

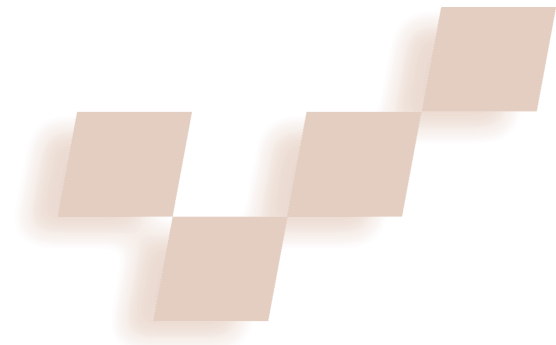
Virtual and Augmented Reality 2020

With roots going back to Ivan Sutherland's research in the 1960s, virtual reality (VR) reached a plateau in the early 1990s when the promise was demonstrable in universities and research laboratories. Although we all knew we had a long way to go, hype overtook the field, leading to impossible expectations. Fortunately, a few years later the Internet became the latest hot topic, leaving VR researchers free to go back to work. Almost a decade later, as Frederick Brooks noted in his keynote talk at IEEE Virtual Reality 99, "VR has gone from 'almost there' to 'barely there'." That's a big step! Perhaps by 2020 we will be "pretty well there." In this article I'll be foolhardy enough to venture a few remarks about progress over the next two decades. However, the safest prediction is that unanticipated science and technology advances will make this forecast seem overly conservative.

Great strides have occurred in generating large VR walk-throughs. For 500K+ polygons, level-of-detail and culling algorithms have been needed to keep latency sufficiently low to maintain the sense of immersion. Improved graphics hardware is rapidly appearing (for example, the Sony Playstation 2), and increased computer power will eliminate polygon counting for most current applications. However, designing database and GIS systems that integrate well with VR applications will arise as a serious issue. Users ranging from urban planners through disaster-relief personnel might need the city of Washington, DC, say, to be accessible, VR-displayable, and interactively modifiable down to the level of electrical circuits and ductwork.

Replacing ergonomically limited head-mounted displays (HMDs) with projective displays such as the CAVE and Responsive Workbench led the move of VR from the laboratory and into the work environment. Head-tracked autostereoscopic displays combined with image-based rendering will eliminate the need for the stereographic glasses that now accompany projective displays. Inexpensive, stereographic flat-panel displays will replace projectors (whichever flat panel technology emerges successful), minimizing display hardware costs and enhancing portability.

Lawrence Rosenblum
Naval Research Laboratory



New display options

Competitor display technologies will also appear. Holography is a likely long-term 3D-display sweepstakes winner, but Workbench-size holographic displays that can support the fast interaction necessary for VR are unlikely by 2020. Direct volume displays will not scale sufficiently to display complex scenes, and their limited interactive capability will remain inadequate for VR. Retinal-scanning displays, which use lasers to "paint" images directly on the eyeball, may become a serious challenger. This technology is nearing commercialization and makes an excellent match for the human visual cognitive system. It can, for example, easily place high resolution in perceptual regions where the eye has many receptor cones and low resolution out on the periphery. It also will be lightweight and inexpensive. However, retinal displays for fully immersive VR require that multiple users share virtual, rather than real, environments. Thus, we would need avatar representations for effective interaction and would have to develop societal control structures for collaboration and interaction. This is achievable over a 20-year time frame.

Creating the interface

With the key visual channel coming under control, the emerging VR challenge is the interface. Integrating natural interfaces with realistic scenes at acceptable latencies puts VR along the way toward recreating Star Trek's "holodeck." Perceptual and multimodal interfaces will replace wands (3D joysticks). Integrated speech and gesture will become the primary interface, and we will have moved from speech recognition toward the requisite use of natural language recognition. Enabled by wide-area tracking technology, navigation will be accomplished by natural actions, such as walking, rather than with data wands, unicycles, or treadmills. The insertion of 3D sound (including second-order effects such as reverberation) is a technology that exists today and will be increasingly integrated into multimodal interaction suites. Environmental effects will be added, so we will feel a hot summer's breeze as our convertible drives through the virtual countryside.

A fundamental component in such user interface design is recognizing a pattern of user intent. Novel computing technologies such as quantum computing, which excels at such nondeterministic tasks as pattern recognition, may add interactive capabilities beyond that expected through advances in solid-state computers.

Adding other elements

The magnetic sensors used today for head and body tracking will be replaced by hybrid sensors that combine sensors such as inertial, acoustic, and RF. By 2020, tiny cameras with images interpreted via machine-vision algorithms will perform tracking functions. Developing machine-vision algorithms that meet VR's demanding latency requirements has proven difficult. However, small retinal cameras (cameras with integrated retinal-like image-processing hardware) are now commercially available. These will become further miniaturized and more capable, enabling their integration into VR-hardware suites without destroying the immersive experience. Real-time computer-vision algorithms for body tracking and gesture recognition will also be developed, resulting in camera-based position tracking for VR.

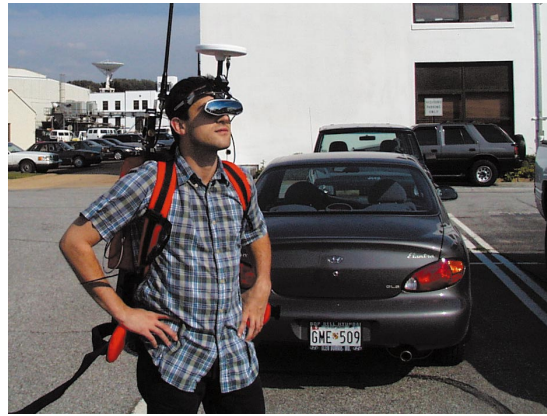
Recent progress on haptics has been impressive, but integrating haptics into the VR suite faces a fundamental limitation. Haptic devices are inherently intrusive, while a goal of VR is the generation of natural, nonintrusive environments. Removing the wires is easy, but constructing haptic interfaces that will feel natural and not impede maintaining the "sense of immersion" is difficult. We can expect lightweight gloves that will provide force feedback and, perhaps, sensory perception. Body suits for bouncing off virtual walls seem less likely. Perhaps micro- or nanoeffectors that provide direct stimuli to muscle groups will offer a solution.

Smell is important for medical and other applications. Doctors tell us that the olfactory channel in the operating room contains significant information. There are only a few seminal efforts to date on olfaction for VR. As critical areas progress, more research attention will focus here. Smell will be part of "CAVE 2020," but without the accuracy or breadth to allow a wine connoisseur to distinguish between a virtual "Chateau Margaux" and a "Chateau Lafite."

Enabling augmented reality

Augmented reality (AR) is the overlaying of computer-generated imagery atop the real world using a see-through display. The use of mobile AR will become commonplace. Use your AR glasses and a wearable computer—a wristwatch, a necklace, or, perhaps, embedded into clothing—to investigate a new city, walk through a museum, or stand in the middle of Pickett's charge at Gettysburg. (See Figure 1.)

Two key AR research issues require solution: (1) spatial registration of real and computer-generated information and (2) information mapping, that is, effective use of the limited space on the see-through display. Registration requires knowledge of the user's position and orientation. Position is obtainable outdoors using GPS receivers and indoors using cameras or sensor systems embedded into the walls. Inertial and magnetic sensors will yield approximate orientation, fine-tuned using machine-vision algorithms to process camera and video data. Even the subvoxel registration demands of medical AR will be achievable by 2020. New data structures, experimentation, and user evaluation will lead to effective information displays. Augmented reality will be used for such applications as maintenance, design, med-



1 Using augmented reality glasses and a wearable computer (here, a backpack), you can investigate a new city.

icine, education, entertainment, and tourism (and for some not anticipated today).

Other technologies impact VR/AR

The network-centric environment required for mobile AR (and also many VR) applications depends on other technology developments (see DeFanti's article in this issue). Great strides will be made toward providing information to users at any location. The generation-after-next of intelligent agent architectures will provide automated, user-specific tools to search through Web-based databases and extract information. Databases will be interactively modifiable.

Suitable hardware are being developed even now. Currently, wearable computers lack high-performance graphics due to power and heat dissipation limitations. These will be solved, leading to very portable graphics computing that will provide VR and AR (almost) anywhere, anytime.

In addition to intelligent agents, cognition aids will enhance the virtual or augmented environment. For example, tracking a person's eye movement may indicate items or topics that a user considers of specific interest. Similarly, the perceptual and multimodal user interaction can be analyzed for clues. Integrating these clues will allow for the modification of virtual and augmented environments without requiring user action.

Finally, computer scientists, psychologists, and sociologists must work together. We must understand the social impact of these new technologies. The benefit will be substantial, but the risk of virtual environments becoming more attractive than reality for a segment of the population is real.

"Meet me in the virtual Baker Street flat, Watson, for the game is again afoot. The aroma of Mrs. Hudson's steak and kidney pie suggests we dine shortly. And be sure to bring the AR gear as well as the Webley revolver, for my memory of London is not what it was in my youth."—S.H. ■

Acknowledgment

I'd like to thank the Office of Naval Research for supporting research projects in VR and AR spanning several topics discussed in this article.

Contact Rosenblum at rosenblu@ait.nrl.navy.mil.